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INVESTIGATION OF VISUAL WORK CAPACITY IN SPACE FLIGHT

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Under conditions of stable weightlessness the mechanical receptors do not furnish information about the surrounding environments, the motion, and the position of the body. Vision serves as the only reliable link between the astronaut and the surrounding world under these conditions. Also the basic information about the performance of the systems on the spaceship is received by the astronaut, just as by flyers, with the aid of vision. Certain authors claim that nine tenths of the entire information is received by flyers with the aid of the visual communication channel and three fourths of all errors made by flyers during the flight is due to the visual analyzer (Stevenson, Fitts).

A spaceship is no exception. The design of manually-operated control systems of the present and future spaceships, the joining of space objects, the landing on other planets, and the work done outside ths spaceship are based, as a rule, on man's ability to detect light signals on some background and to identify various types of visible shapes. It is, therefore, clear that the level of functional possibilities of the astronaut's vision during his travel in space is important and why considerable attention is paid to this analyzer.

Prior to the space flights, it was assumed that the absence of gravity might deform the eyeball and change the functional abilities of the vision analyzer. It was expected that the moving system of the eyes would in some way lose the ability to coordinate motions, which was acquired during its lifetime and, as a result, would affect the functions of vision: It would impair the vision in depth, disrupt the processes of accommodation and convergence, etc.

All of these had to be checked before the first travel in space made by man. The early experiments were performed on air-crafts flying along a Kepler curve where it was possible, although only for a short duration, to obtain a state of weight-lessness.

In addition, there appeared theoretical premises based on the knowledge of the medium to be encountered by an astronaut. For example, as early as during the Tenth International Astro-nautical Congress in 1959, Kh. Shtrukhgol'd compared the condi-tions of an astronaut's vision function with the vision in depth. He emphasized that the stars will appear brighter to the astronaut and the moon will be blinding (by 30% more than when observed on the earth). The sky of the cosmic space is ten times less illuminated than the night sky observed on the earth.

Experiments were carried out on aircrafts under conditions of short-duration weightlessness.

American specialists taking part in such flights have noted a reduced sharpness of vision by an average of 6%. Interesting data were also obtained by Soviet medics. For example, under conditions of short-duration weightlessness, L. A. Kitayev-Smyk observed a dilution and warping of visible objects. Upon investigating the perception of color, he found an increase in the brightness of the colors -- yellow in particular. Some operators observed a violet aureole around luminous objects.

Investigations have shown that the sharpness of vision is reduced in the condition of weightlessness; some persons, how-ever, have had their sharpness of vision restored, and, when remaining in the state of weightlessness a little longer, the original level was even exceeded.

However, the results of the investigations carried out in flights along a Kepler curve did not, of course, yield a complete picture because during the 30--40 sec, the organism had no time to adjust itself to the conditions of weightlessness. The obtained information can be considered only as indicating certain transitional values of the studied function.

Therefore, as soon as an opportunity appeared, it was possible to carry out the investigations in the environments of space travel. The investigation program of the spaceship "Voskhod" included the study of the resolving power of the vision analyzer of the astronauts. The sharpness of vision was checked with the aid of a set of standard target marks pasted on the log-book of the ship. The target marks had to be observed at a distance of 300 mm.

In order to disclose the relationship between the values of the vision sharpness determined by conventional methods and the method used in our tests, it was necessary to carry out a series of correlated tests. The sharpness of vision of the tested persons was first determined with the aid of Sivtsev's tables (Landol't rings) and later by the target marks. The obtained results disclosed a high degree of correspondence of the sharpness of the visions determined by these two methods.

The resolving power of the vision analyzer of the astronauts was determined even before the flight by laboratory investigations. For this purpose, both the main and stand-by personnel of the crew were utilized. Tests were also made during the trainings on a training ship in accordance with the flight program. The results of these experiments were needed for comparison with the results obtained in flights.

The sharpness of vision of the astronauts was determined during the fifth and sixth orbits and that of B. B. Yegorov and V. M. Komarov was also determined at the beginning and end of the flight. The obtained results testify that the resolving power of the vision remained almost unchanged for all astronauts during the entire flight. The insignificant variations noted when analyzing the obtained data were within the value allowed for errors of this method.

The visual work capacity of the astronauts was also tested during the flights of the "Voskhod" spaceships.

The target marks and the test tables made it possible to determine the operational work capacity. For this, the operator is required to find the element of the target mark in which he can count the number of marks by holding the target at a distance of 300 mm. Such a voluntary selection of the element of the target marks eliminates the effect of the sharpness of vision on the result of the test, because the tested person in any case used an element of the target marks which, according to calculations, exceeded his threshold of vision.

This method was first tested in laboratory experiments and the obtained data were used for a comparison with those obtained during a flight.

The "above-threshold" increase in sharpness of the astronaut's vision is shown in Fig. 1. For example, the target marks selected by the astronauts for their work were on the average 20% higher than their threshold of vision, except those of B. B. Yegorov with a value close to 42%.

The data on the visual work capacity of the members of the crew of "Voskhod-2" is shown in Fig. 2.

The cited data indicate that the operational visual work capacity is considerably reduced on a spaceship. This is apparently due to the fact that weightlessness disrupts not only the overall coordination of motion but also the coordination of the group of eyeball-moving muscles. Under the new conditions, their intensified effort to change the fixing point becomes excessive and, as a result, the glance acts as if it "skips" the required point. The eye must be tuned differently than it was before and this is difficult to accomplish because a new impulse arrives at the expiration of 0.01 sec which skips during the period of the refractory phase. However, in case of larger parts, this phenomenon is not observed because an increased resolving angle reduces sharply the frequency of the impulses.

Interesting data on the comparative characteristics of individual elements of the operational work capacity of the astronauts were obtained at different stages of the flights (Fig. 3). For example, while a stability of indicators was noted in the case of V. M. Komarov, there was an insignificant impairment of these functions in the case of B. B. Yegorov as the flight in space continued to develop.

Data were also obtained on the perception of different colors of objects during a flight in space. Our aim was to investigate the perception of colors of objects inside a spaceship by using a special table for this purpose. It contained six bands of different colors located next to black-white graded wedges.

It is known that all colors approach that of black as their brightness decreases. Therefore, a comparison of the brightness of any color with the brightness of the grades of a black-white wedge serves as an objective indicator of its brightness. Three basic colors (red, green and blue) and three of their complementary colors were selected for the investigation. During the travel in space, an astronaut had to find for each color a black-white range of wedges whose brightness would be the same. A black-white wedge made it possible to measure the brightness of the objective colors within its tenfold change. The average value of the error of a single determination of the brightness of a color is equal to 15--30% according to this table. A statistical processing of repeated measurement taken during the flight made it possible to reduce it to 5--6%.

A comparison between the results obtained by testing and in-flight investigations carried out in daylight made it possible to disclose the differential changes in the perception of colors of objects. The level of the functional stability of chromatic vision is substantially affected by a series of conditions, such as color adaptation, simultaneous and successive contrast, special features of the process of comparing, etc. It was necessary to take these conditions into account and to explain the net effect of weightlessness on the investigated function of vision. For this, the root-mean-square error of a single equalization of the brightness of the color's and black-white fields was derived. The measurements taken at different times and with different color tables have shown that its value for the employed colors is equal to ±7.8%.

During the flight of the spaceship "Voskhod-2" there was established a noticeable reduction in the subjective brightness of the colors observed by the astronauts. The average reduction of the brightness of all colors was equal to 26.1% for P. I. Belyayev and 25% for A. A. Leonov. A maximum deviation was observed in determining the brightness of the purple, azure, and green colors and a smaller deviation was in the red color. The reduction in the brightness of all other colors of objects did not exceed 10%. It should be noted that there was not a single case showing an increase in brightness of the exhibited colors.

The reason for such a large reduction in brightness of individual colors taking place under conditions of weightlessness is not yet explained and its disclosure requires additional and more thorough investigations.

There is also still another method of analyzing the dynamics of the resolving power of the visual analyzer during a flight. It deals with the individual reports of the astronauts on the visual observation of the earth's surface and of objects in space. An analysis of these reports and the theoretically calculated vision of the astronauts are shown in the Table.

The Table shows that the sharpness of vision during an orbital flight is higher than the average standards; it pertains, however, only to objects which extend linearly (highways, inverse tracks, etc.). However, under conditions on the ground, the sharpness of vision applicable to these objects is also higher and in several cases it is even higher in a larger degree than shown in the Table. This was mentioned, in particular by S. V. Kravkov, as early as 1936.

Theoretically Calculated Sharpness of Vision of Astronauts According to Their Individual Reports

Observed objects	Approximate value of objects, angular minutes	Sharpness of vision
	not less than:	more than:
Rivers of Amazon, Volga, Nile types	10-20	0.1-0.5
Large highways	0.2-0.5	5-2
Take-off - landing strips	0.5-1.0	2-1
Ships in shipyards	0.3-1.5	3-0.7
Cruising ships	1-3	1-0.3
Inverse tracks of aircrafts	0.2-0.4	5-2.5
Beach strip (Caucasus)	0.3-0.5	3-2

In the American press, interesting data on the individual reports of the astronauts (Aviation Week, 1965, No 9, Geze, 1965 and others) were published. For example, Cooper observed automobiles on highways, Conrad saw three airplanes in the air, Borman observed the launching of a rocket and saw the Panama Canal, etc.

There is no doubt that in this case a sharp increase in the sharpness of vision during a flight is noted which can be explained by the object's extension (trains of dust left by the automobiles, the inverse tracks of the airplanes, etc.). Remaining somewhat unexplained, however, is the mechanism of the large increase in sharpness of vision of the astronauts Cernan and Stafford who saw an airplane on the ground and even determined its name. Yet, the experiments carried out on the spaceship "Gemini-11" to study the resolving power of vision do not, according to the tests made on the ground, make it possible to claim a sharp increase in the function of the vision analyzer. For example, out of 12 rectangles located on the ground, the astronauts identified only three and the numerals in two of them were incorrectly named.

The carried-out investigations show that during travel in space the functional abilities of the visual analyzer undergo definite changes. While the accumulated information is still inadequate and certain aspects require a further study, it can be claimed, even now, that it is necessary to disclose the peculiarities of man's vision under conditions of space travel. This pertains to specialists developing the instruments and indicating facilities and also to persons who train the astronauts for travel in space.